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SCHEDULE Same 16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited. 17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, If different from Report) 18. SUPPLEMENTARY NOTES None 19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Pattern Recognition Interactive Processing Feature Extraction Modem Signature Analysis In-Service Performance Tests Classifier Design 20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report describes the design and evaluation of classifiers for distinguishing four types of modems: the CODEX LXI-9600, the HUGHES HC-276, the PARADYNE LSI-96, and LENKURT 26-C. The data used to develop these classifiers consisted of many digitized time sample waveforms for each modem and was collected by RADC's Digital Communication Experimental Facility (DICEF). With the Waveform Processing System (WPS) capabilities, the Interactive Processing Section

of the Information Sciences Division (ISCP) analyzed this waveform data and extracted an initial set of eighty features. This initial set was later -

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modified to fifty features. The On-Line Pattern Analysis and Recognition System (OLPARS) was then used to develop a number of classifier designs which are based on different subsets of the initial fifty features.

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I. INTRODUCTION

The ultimate objective of this project is to determine the potential use of modem signal signatures as in-service indicators of transmission channel degradation and possibly as diagnostic aids. Toward this end, digitized time samples of modem signals impaired by channel perturbations were recorded on magnetic tape in RADC's DICEF (Digital Communications Experimental Facility). This objective was broken up into two parts:

- a. Modem Identification.
- b. Measurement of the Channel Perturbations.

The Waveform Processing System (WPS) and the On-Line Pattern

Analysis and Recognition System (OLPARS) were used to identify

algorithms for the modem identification. Measurement of the channel

perturbations are not covered in this report.

Specifically, the following sequence of tasks was employed:

- a. Data Collection
- b. Data Analysis
- c. Feature Hypothesis
- d. Feature Extraction
- e. Feature Evaluation

- f. Classification Logic Design
- g. Testing classification logic designs with Independent Test

The classifier designs discussed in this report are based entirely on the data collected by RADC's DICEF.

8. Hearmanner of the Channel Perturbations.

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a. Feature Evaluation

II. BACKGROUND ON FACILITIES USED

A. The Waveform Processing System (WPS).

The Waveform Processing System is an interactive, graphics-oriented computer system for the extraction of features from digitized waveform data and the analysis of a digitized waveform data base. Its chief purpose is to provide the analyst with a library of mathematical algorithms and display options he can call upon from the display console so that he can design and evaluate feature extraction techniques for waveform pattern recognition problems. Once a set of features has been extracted from each of the members of a waveform data base, the analyst can input them into the OLPARS System to begin the pattern classification logic design phase of the problem solution.

The Waveform Processing System is implemented on a DEC PDP-11/45

Computer with a Vector General dislay and control console, and a

Tektronix 4002 storage tube with a hardcopy unit for hardcopying

selected Vector General displays.

The system includes its own executive software, filing system, display package, and a library of application programs. A feature extraction language allows the analyst to construct his own algorithms for waveform processing and feature extraction.

The input to WPS is in the form of digitized waveform data. The system is built as a series of overlays which are callable by the operator from a menu which is displayed to him on the Vector General

CRT. The data in the form of data trees is available to the analyst by means of utilizing the interactive devices on the Vector General console.

B. The On-Line Pattern Analysis and Recognition System (OLPARS).

OLPARS is an interactive, graphics-oriented computer system for the solution of pattern analysis and pattern classification problems.

OLFARS is resident on two systems. One version is on the PDP-11/45 Computer under WPS. This is a single user system employing high performance interactive graphics, and, as a module under WPS, provides for ease of interaction between the feature hypothesis mode conducted under WPS and a rapid testing of these hypothesis under OLPARS. However, since this system resides on a minicomputer, there are core limitations in terms of the size of the data base which can be processed.

A second version of OLPARS is implemented on the HIS 6180 Computer under the MULTICS Operating System.

Both versions of OLPARS include their own executive software, filing system, display package, and software modules for feature evaluation, vector data structure analysis, measurement transformation, and classifier logic design.

C. Digital Communications Experimental Facility (DICEF).

The Digital Communications Experimental Facility (DICEF) is a unique

laboratory dedicated to data acquisition and analysis, research and development in support of digital communications. This facility provides a combination of programmed data reduction capabilities and a variety of in-place real and simulated channels to allow a wide choice of equipment and media experiments. Media simulators provide controlled, repeatable channel conditions essential to conduct valid comparative analysis of communications equipments. Units evaluated in this mode are subjected to numerous combinations of known perturbations which can be controlled in a completely deterministic manner. Regardless of whether real or synthetic media are used, correlation of error performance to channel characteristics can be obtained. This capability is provided by the heart of the facility - a high-speed communications processor, the 9303 Message Switch, which operates at any data rate up to ten megabits per second. The communications processor possesses the critical attribute of a high-speed I/O so that all information regarding high data rate channels can be acquired and manipulated in real time.

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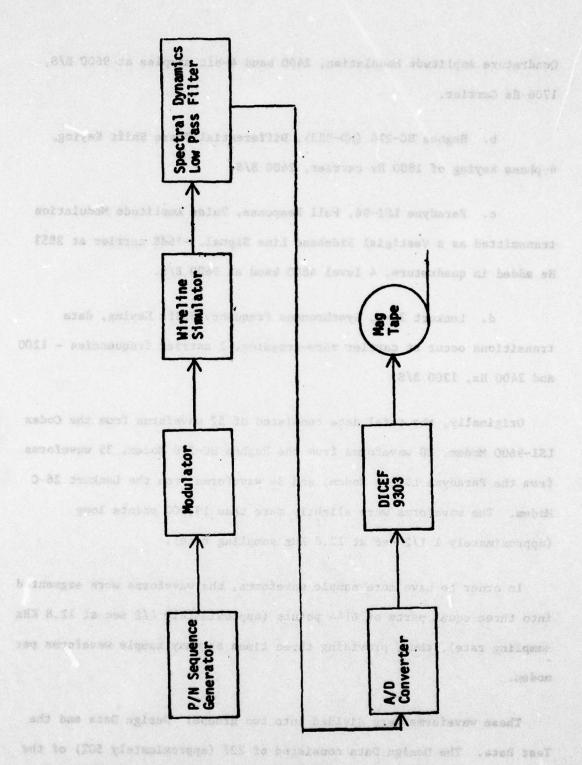
III. DATA COLLECTION

Several digitized time samples of modem signals impaired by telephone channel perturbations were recorded (magnetic tape in RADC's DICEF (Digital Communications Experimental Facility). A block diagram of the test configuration is shown in Figure 1. A 2047 bit maximal length psuedorandom digital sequence generator was used as the data source. The unit used was II Corporation's BERT 901 with an RS-232 output compatible with all modems tested. The analog output of the modem was then applied to DICEF's Wireline Channel Simulator. The two technical manuals describing the operation of this simulator are listed as References 4 and 5.

All frequency components beyond half the sampling rate were removed by the anti-aliasing low pass filter portion of the Spectral Dynamics SD-360 Digital Signal Processor. The analog signal was then Analog-to-Digital converted using a 12-bit converter with a 12.8 KHz sampling rate. The digital samples were recorded by DICEF's 9303 processor on its 7-track magnetic tapes. These tapes were subsequently converted to 9-track WPS compatible tapes by RADC/ISCP.

Following is a short technical description of the four modems employed:

a. Codex LSI-9600, Double Sideband Suppressed Carrier



TEST CONFIGURATION - AFCS MODEM SIGNATURE ANALYSIS
FIGURE 1

Quadrature Amplitude Modulation, 2400 baud 4-bit samples at 9600 B/S, 1706 Hz Carrier.

- b. Hughes HC-276 (MD-823), Differential Phase Shift Keying,
 4-phase keying of 1800 Hz carrier, 2400 B/S.
- c. Paradyne LSI-96, Full Response, Pulse Amplitude Modulation transmitted as a Vestigial Sideband Line Signal, -16dB carrier at 2853 Hz added in quadrature, 4 level 4800 baud at 9600 B/S.
- d. Lenkurt 26-C, Synchronous Frequency Shift Keying, data transitions occur at carrier zero-crossing, 2 carrier frequencies - 1200 and 2400 Hz, 1200 B/S.

Originally, the total data consisted of 52 waveforms from the Codex LSI-9600 Modem, 30 waveforms from the Hughes HC-276 Modem, 35 waveforms from the Paradyne LSI-96 Modem, and 34 waveforms from the Lenkurt 26-C Modem. The waveforms were slightly more than 19,800 points long (approximately 1 1/2 sec at 12.8 KHz sampling rate).

In order to have more sample waveforms, the waveforms were segmented into three equal parts of 6144 points (approximately 1/2 sec at 12.8 KHz sampling rate), thus, providing three times as many sample waveforms per modem.

These waveforms were divided into two groups: Design Data and the Test Data. The Design Data consisted of 227 (approximately 50%) of the 453 waveforms and were used to design the classifier. The Test Data

consisted of the remaining 226 waveforms and were later to be used as a test of the classifier. Specifically, these data sets are as follows:

pandy deported "ope" of deTOTAL DATA

MODEM

Codex LSI-9600	156 Waveforms
Hughes HC-276	90 Waveforms
Paradyne LSI-96	105 Waveforms
Lenkurt 26-C	102 Waveforms
TOTAL	453 Waveforms

DESIGN DATA

MODEM

Codex LSI-9600	78 Waveforms
Hughes HC-276	45 Waveforms
Paradyne LSI-96	53 Waveforms
Lenkurt 26-C	51 Waveforms
TOTAL	227 Waveforms

TEST DATA

MODEM

Codex LSI-9600	78 Waveforms
Hughes HC-276	45 Waveforms
Paradyne LSI-96	52 Waveforms
Lenkurt 26-C	51 Waveforms
TOTAL	226 Waveform

It is important to have in mind that all of the data collected was used for the modem identification portion of the effort. All but one of the waveforms for each modem was impaired with varying degrees of

different types of distortions (phase jitter, Gaussian noise, harmonic distortion, and combinations of these). As our results will indicate, the features utilized were powerful enough to "see" through these distortions and properly classify the waveforms' origin (modem).

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IV. DATA ANALYSIS AND FEATURE EXTRACTION

A. General.

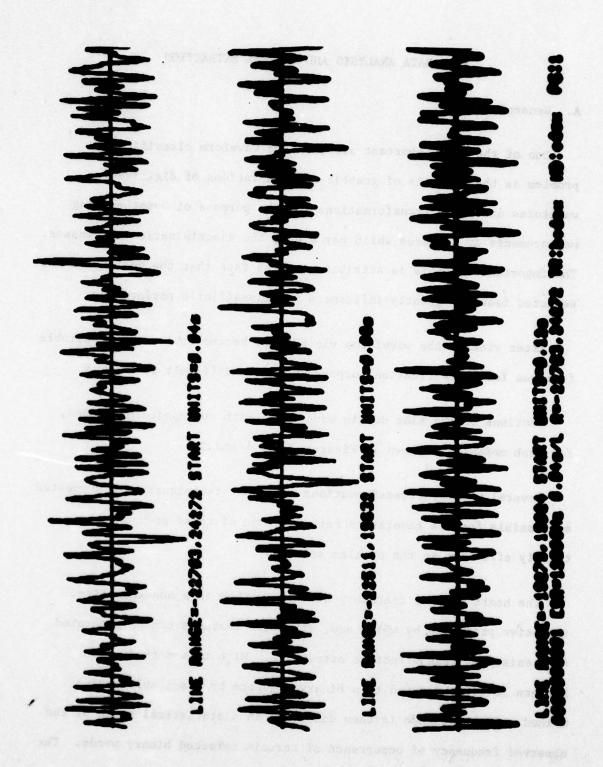
One of the most important steps in the waveform classification problem is the analysis of graphic representations of digitized waveforms and their transformations for the purpose of hypothesizing measurements or features which may aid in the discrimination of classes. The importance of this is attributed to the fact that the quality of the selected features greatly influences the classifier's performance.

After viewing the waveforms via WPS, it became obvious that suitable features for classification purposes would be difficult to come by.

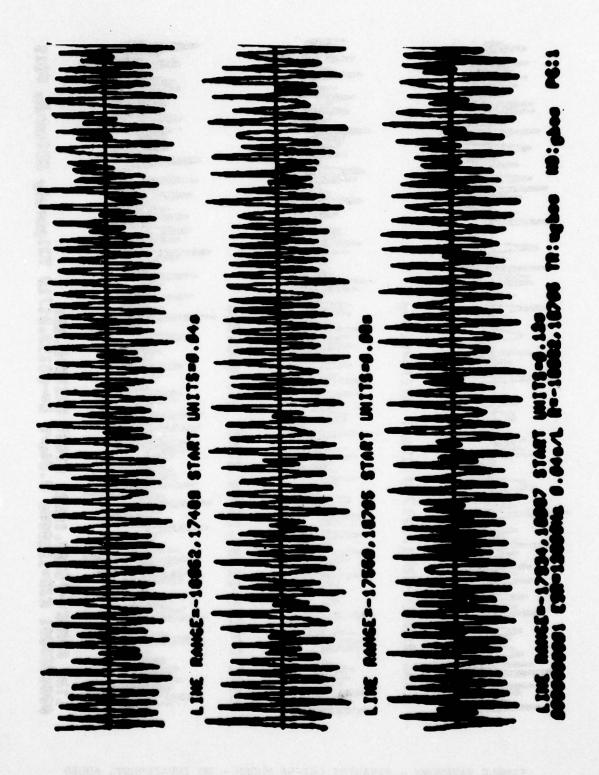
Sections of the time domain waveforms, with no impairments added, for each modem, are shown in Figures 2, 3, 4 and 5.

Several waveform transformations and other techniques were suggested as possible feature generation methods. One of these proved to be totally effective in the problem solution.

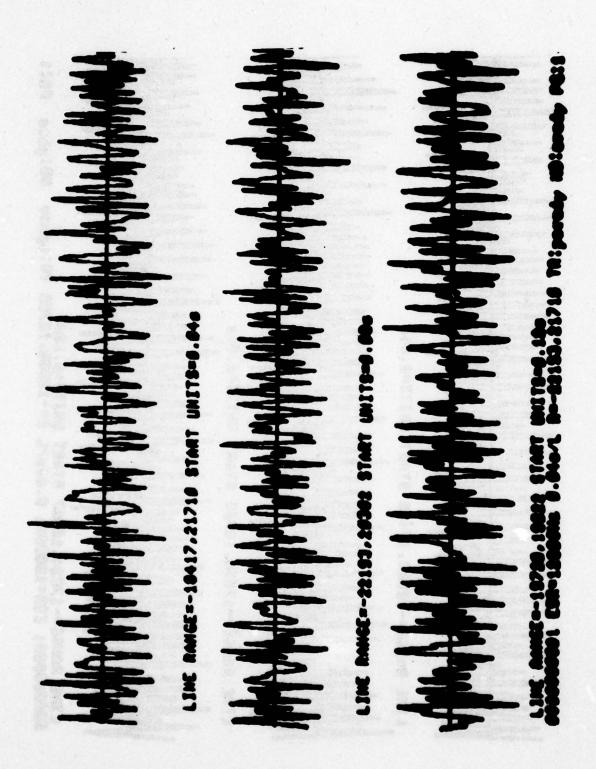
The heart of this feature generation method is a nonexhaustive, iterative procedure by which new, effective features can be generated from existing, less effective attributes. With this method, each pattern is first reduced to a binary sequence by a suitable coding method. Each sequence is then described in a statistical sense by the observed frequency of occurrence of certain selected binary words. The categorization of the patterns is performed on the basis of such



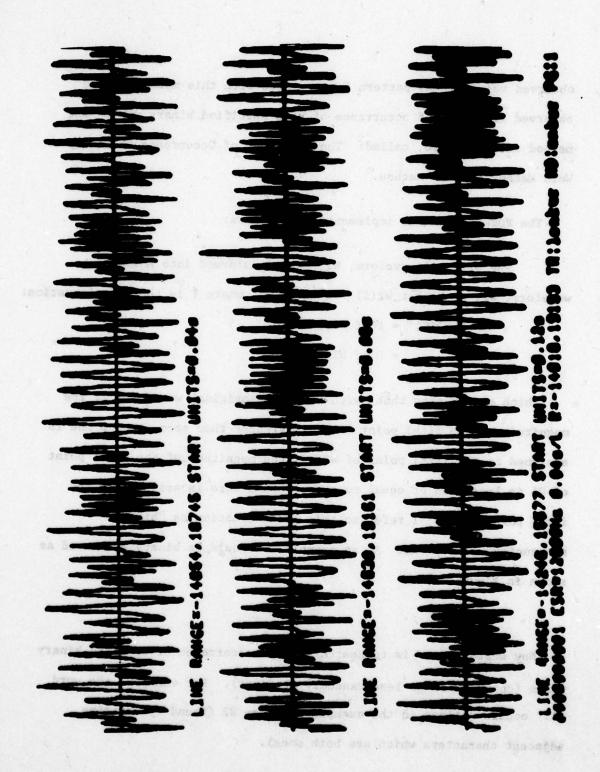
SAMPLE WAVEFORM - CODEX LSI-9600 MODEM - NO IMPAIRMENTS ADDED FIGURE 2



SAMPLE WAVEFORM - HUGHES HC-276 MODEM - NO IMPAIRMENTS ADDED FIGURE 3



SAMPLE WAVEFORM - PARADYNE LSI-96 MODEM - NO IMPAIRMENTS ADDED FIGURE 4



SAMPLE WAVEFORM - LENKURT 26-C MODEM - NO IMPAIRMENTS ADDED

sood bloom be at years driv "it" FIGURE 5 to communicate and rod double.

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observed values. Any pattern feature used with this method is the observed frequency of occurrence of some specified binary word. The method is, therefore, called: The Frequency of Occurrence of Binary Word Method or FOBW Method.

The FOBW Method was implemented as follows:

The original waveform, W1, was transformed into a second waveform, W2, such that W2(i) = T[W1(i)], where T is the transformation:

$$T[W1(1)] = 1 \text{ if } W1(1) > 0$$

= 0 if $W1(i) \le 0$

Which simply says that, with Wl as the original waveform, if the magnitude of the i(th) point of Wl is greater than zero, then a one is assigned to the i(th) point of W2; if the magnitude of the i(th) point of Wl is less than or equal to zero, then a zero is assigned to the i(th) point of W2. I refer to this transformation as "binary sequencing" a waveform. As an example, Wl would be binary sequenced as shown in Figure 6.

Now what is done is to search for the occurrence of specific binary words (chosen more or less randomly at first). For example, the word "11" occurs 7 times in the example waveform W2 (found by counting adjacent characters which are both ones).

Finally, the concept of "delays" is introduced. If we were to search for the occurrence of the word "ll" with delay 1, we would look

W1

at the first character, skip one, and lock at the third; than we mould

SW

originally engrebed for the occurrence of the binary words bill", "10";

he given word with a specific delay.

EXAMPLE OF BINARY-SEQUENCING A WAVEFORM

mr) "10" ber "Gi" abset ads Hillw : PIGURE 6 bes ("00" been add mett saedt

at the first character, skip one, and look at the third; then we would go to the second, skip one, and look at the fourth; and so on. The occurrence of "11" with delay 2 would be calculated by taking the first character, skipping two, and taking the fourth; then the second character with the fifth; and so on. As in our previous example, if no delay is present, adjacent characters are compared. The notation would be as follows:

for W2 = 011110000001111100001

FOBW(11)0 = 7

FOBW(11)1 = 5

FOBW(11)2 = 3

FOBW(11)6 = 2

for delays 0, 1, 2, and 6 respectively.

In our case, the waveforms were 6144 points long (approximately 1/2 sec at 12.8 KHz sampling rate). They were binary sequenced and were originally searched for the occurrence of the binary words "11", "10", "01", and "00". The delays used were 0, 10, 20, 30, 40, 50, 60, ..., 170, 180, 190; for a total of 20 different delays. These were chosen at random. Resulting for each waveform was an 80 dimensional (4 words x 20 delays) vector; each feature representing the number of occurrences of the given word with a specific delay.

As experience with the FOBW Method was acquired, it was noted that there was some redundancy in the features obtained by the word "11" with those from the word "00"; and likewise with the words "10" and "01" (in

general, this redundancy is not to be expected). Also, potentially better delays were arrived at. As a result of these findings, the program was modified to search for the words "11" and "10" with delays 0, 1, 2, 3, ..., 23, 24. Now, resulting for each waveform was a 50 dimensional (2 words x 25 delays) vector. A listing of the feature extraction programs and all other programs used are provided in Appendix A.

B. Specific.

The Design Data Waveforms were binary sequenced and the feature extraction algorithm was executed on each of the binary sequenced waveforms. This algorithm searches for the words "11" and "10" with delays 0, 1, 2, 3, ..., 23, 24. For each waveform, a 50 dimensional (2 words x 25 delays) vector is computed.

At this stage, we have a tree that has four nodes (classes) with a total of 227 50 dimensional vectors. This set of vectors, which contains the extracted features, is then used for the classifier design. Once the classifier has been achieved, the TEST DATA is binary sequenced, the features are extracted and these are then used as a test for the classifier's efficiency in discriminating the four classes. The design data tree structure is as follows:

percent this redundancy is not to be expected). Also, potentially better delays were arrived at. As a result of those findings, the pregram was modified to search for the words "II" and "IO" with delays 0, 1, 2, 2, ..., 23, 26. Now, vessiting for each waveform was a 50 dimensional (a words x 25 delays) when he had age of the feature entraction programs and all oths (color used are provided in Appendix A.

CODEX 78 HUGHE 45 PARAD 53 LENKU 51

extraction algorithm was executed on each of the binary sequenced waveforms. This algorithm searches for the words "11" and "10" with dalays G. 1. 2, 3. . . . 23, 2s. For each waveform, a 50 dimensional (2 words a 25 delays) vector is computed.

As this stage, we have a tree that has four modes (classes) with a total of 227 50 dimensional vectors. This set of vectors, which contains the entraored Features, in them used for the classifier has been monteved, the 1857 SAIA is binary sequenced, the factorys are extracted and these are then used as a test for the classifier's officiency in discriminating the four classes. The design days free entraction is as fallowed.

V. MEASUREMENT EVALUATION

We are now concerned with the discriminatory qualities of our fifty measurements. In general, we would like to use the minimum number of measurements that achieves a satisfactory solution. The OLPARS provides two suboptimal methods for ranking the discriminatory power of the extracted features. Each of these methods provides for three types of rankings. The first type uses a significance measure of a particular feature, xp, for discriminating class i from class j and is designated Mij(xp). The second type of ranking uses a significance measure of xp for discriminating class i from all other classes and is designated Mi(xp). The last type uses a measure of the overall significance of xp for discriminating all classes and is designated M(xp).

The first method on the OLPARS for ranking features is the discriminant measure which is useful when the class conditional probability distributions are unimodal. These discriminant measures, using feature xp, are defined as follows:

Mij(xp) =
$$\frac{[\bar{x}p(1) - \bar{x}p(j)]^2}{[(Ni-1)(\hat{\sigma}p(1))^2 + (Nj-1)(\hat{\sigma}p(j))^2]}$$

where xp(j) = the estimated mean of class j along measurement xp,

 $\hat{O}_{p(j)}$ = the estimated standard deviation of class j along measurement xp,

and Ni - the number of vectors from class i.

The discriminant measure for differentiating class i from all other classes using measurement xp is defined as:

$$Mi(xp) = \sum_{j \neq i} Mij(xp)$$

Finally, the discriminant measure for distinguishing all classes using measurement xp is defined as:

where K = the number of classes.

The other OLPARS feature evaluation method is the probability of confusion measure. It is valid for any probability distribution since it essentially measures the overlap of the class conditional probabilities.

Since the functional forms of the class conditional probabilities are not known, OLPARS estimates the marginal class distributions using the sample data. The range for measurement xp is divided into cells of width A. The probability that a sample from class j will occupy the r(th) cell along the range of measurement xp is given by:

The probability of confusion measures are defined as follows:

The pairwise measure for differentiating class i from class j can be computed by:

$$Mij(xp) = \sum_{r=1}^{N_p} \min_{i,j} (Prp(i), Prp(j))$$

The measure for differentiating class i from all other classes using measurement xp is defined by:

$$Mi(xp) = \sum_{j\neq i}^{K} Mij(xp)$$

Finally, the overall measure of significance of measurement xp for differentiating all classes is computed as follows:

$$M(xp) = \sum_{i=1}^{K} Mi(xp) = \sum_{i=1}^{K} \sum_{j\neq i}^{K} Mij(xp)$$

The ranking of the extracted features based on these evaluation techniques provides the information required to rationally choose initial subsets of the fifty features for logic design.

VI. LOGIC DESIGN

Logic design is an iterative process in which many designs, based on modified versions of the initial feature subsets, are generated and tested. Features which appear to discriminate between the more troublesome classes are added, while superfluous features which rank high for the same easily discriminated classes are eliminated.

The logic for the classifiers for this pattern recognition problem are based on two approaches: the Pairwise Fisher Linear Discriminant Technique and User-Defined Logic based on coordinate vector projections. In the Pairwise Fisher Linear Discriminant Technique, for each pair of classes i and j a unit vector dij is computed such that projections of the data onto dij maximize the ratio of the between-class scatter to the within-class scatter. The direction dij which maximizes this ratio is given by:

where Wij = (Ni - 1)Ci + (Nj - 1)Cj

Ci = Estimated Covariance Matrix for class 1

रिय - मिर - मिर

Hi = Estimated mean vector of class i

Ni = Number of vectors in class i

and α = Normalizing constant so that $|\mathbf{d}| = 1$

OLPARS computes dij and an initial threshold, 01j, to distinguish

between all pairs of class. These thresholds may be adjusted, if necessary, to obtain optimal discrimination along each dij.

For example, the inner product of an unknown input feature vector, x, is taken with the discriminant dCH for the pair consisting of CODEX LSI-9600 and HUGHES HC-276, and compared with the threshold θCH for that pair.

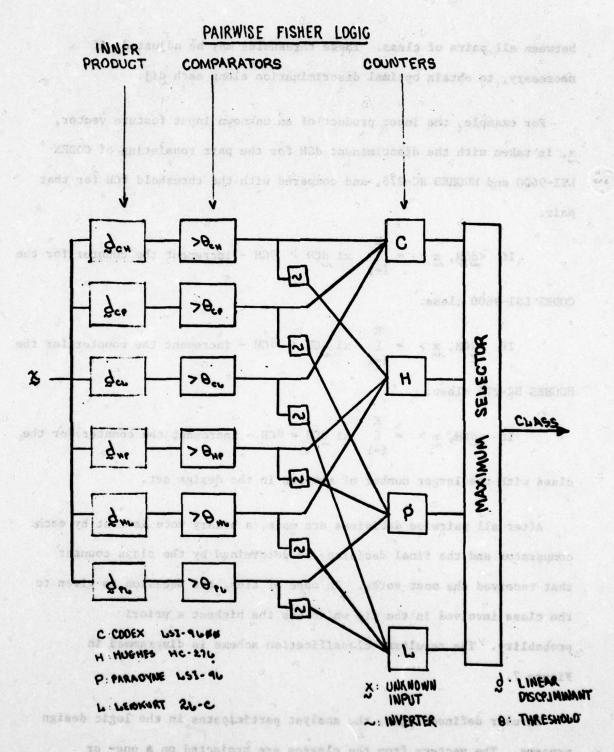
If < dCH, $x > = \sum_{i=1}^{K} xi dCH > \theta CH - increment the counter for the counter for the counter large.$

If $\langle dCH, x \rangle = \sum_{i=1}^{K} xi dCH < \theta CH$ - increment the counter for the HUGHES HC-276 class.

If < dCH, $x > = \sum_{i=1}^{K} xi dCH = \theta CH$ - increment the counter for the class with the larger number of samples in the design set.

After all pairwise decisions are made, a binary vote is cast by each comparator and the final decision is determined by the class counter that received the most votes. In case of ties, the decision is given to the class involved in the tie which has the highest a priori probablity. The resultant classification scheme is diagrammed in Figure 7.

In user defined logic, the analyst participates in the logic design process. The vectors from the classes are projected on a one- or two-space. If there is (in the analyst's judgment) sufficient



PAIRWISE FISHER LOGIC - CLASSIFICATION SCHEME
FIGURE 7

separation between classes, or between groups of classes, boundaries may be drawn so that the feature space is partitioned into two or three regions. These regions are then labeled as to the class or classes present in them. Figure 36 in Experiment 8 illustrates partitioning into three regions.

For the one-space implementation of these logics, the mathematics is extremely simple. The unlabeled vector to be classified is projected (dot product) onto the projection direction (discriminant); the value of this scalar is then compared to the value of the boundary (threshold drawn by the user). All user defined logics in this report are in one-space logic, however, a two-space scatter plot of the logic designed in one-space using features 4 and 27 is given in Figure 37.

VII. EXPERIMENTAL RESULTS TEALS DESCRIBED ADDRESS OF THE PROPERTY OF THE PROPE

Nine classifiers were designed. The first four classifiers are based on the pairwise Fisher Linear Discriminant Technique. The remaining five classifiers are decision trees which use one-dimensional coordinate vector logic at each node. Figure 8 lists the features used for each design (experiment).

All classifiers were designed using the Design Data set. These classifiers were evaluated with the Design Data set and an independent Test Data set (these two data sets are described in a previous section).

The Design and Test confusion matrices, with their statistics, from the resulting evaluation of each classifier are given for each experiment. The histograms of the data projected along the features in the decision trees using coordinate vectors in one-space are also given for Experiments 5 through 9. The logic tree structures for these five experiments are also shown. In the case of Experiment 8, the two-space scatter plot with reference to the two features used in that experiment is included.

EXPERIMENT 1

BARADITORNI STRINDING TARS BY STRANG SINT

SCHOOL MEETINGS IN 1000 BOOK

5 9 15 25

EXPERIMENT 2

30 34 40 50

EXPERIMENT 3

2 5 9 21

EXPERIMENT 4

27 30 34 46

EXPERIMENT 5

29 30 34

EXPERIMENT 6

27 34 46

EXPERIMENT 7

3 8 27

EXPERIMENT 8

4 27

EXPERIMENT 9

27 29

LIST OF FEATURES USED IN EACH EXPERIMENT FIGURE 8

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						68 66	983 60 0	REJECTED	9	8	9	8	
DATA TREE . 222						0 21 (RIMERT A 34 46	TREE 22	/ ERROR	0.00x	8.69%	N. 88%	N. COX	
DATA							DATA	ERROR	5	9	0	0	
222	•	8	5	5	9		ξ 2 1ξ 23	CORRECT	20.00x	200.00	290.00	200.00	/00.001 /00.001 /00.00
	*·	2	9	9	92 82) E 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	`	100.00x	100.001	100.06%	100.001	FOR 188.88/ FOR 6.88/ FOR 8.88/
LUGIC TREE ZZZ	₩.	3	9 9				TREE 222	CURRECT / CORRECT	51 100.00x	53 100,00%	45 100.00%	78 100.00%	. 3
				5	78	AB THERE T) E 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	`					FOR 16 FOR

DESIGN CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 1 FIGURE 9

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		LOGIC TREE	TREE 999	DATA	DATA TREE 999		
	a	· u	*. *:				
1 1 N N N N N N N N N N N N N N N N N N	51 6	2	0.00.00				
٥	ы 51	2 S S	1 0				
w.	9 6	45	3				
×	0 1	9	77, 683 0				
	· ·						
		70010	LOGIC TREE 999	DATA	DATA TREE 999		
CLASS	TOTAL	CORRECT	CT / COMRECT	ERROR	/ ERROR	REJECTED	/ REJECTE
-	51	51	168.66%	9	N. 00x	0	B . 68 x
a	52	51	98.07%	-	1.92%	39	N. 66%
E E	45	45	100.001	0	200.0	53	8.0ez
×	78	11	98.71%	-	1.28%	3	מיחקא
TOTAL UVERALL UVERALL UVERALL	VECTORS CORRECT ENROR REJECTED	226	FUR 99.11/ FUR 0.88/ FOR 0.06/				

TEST CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 1
FIGURE 10

31

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			\$ (a (a + 5)					/ REJECT	8.00x	0.00x	0.60x	8.66×	
								REJECTED	9	3	9	20	
DATA TREE XXX							DATA TREE XXX	ERROR	200.0	793°A	No 100 x	200.0	
DA							DAT	T ERROR	3	9	20	20	
EE XXX	*.	9	0, 90 0	2	u 87		EE xxx	/ CUKRECT	100.001	100.001	100.001	166.00%	227 227 FOR 100.007 0 FOR 0.007 0 FOR 0.007
LOGIC TREE	M 1	3	68.8	45	0.21		LOGIC TREE XXX	CORRECT	51	53	45	7.8	227 227 FOR 8 FOR
	۵ ۲	51 8	6 53	9 9	9			TOTAL	51	53	45	18	TOTAL VECTORS OVERALL CORRECT OVERALL ERROR OVERALL REJECTED
		n .	Ģ	اندا لا	×	07.40		CLASS	5	0	A	×	TOTAL DVERALL DVERALL OVERALL

jE0

DESIGN CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 2

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								/ REJ	6.6 6	6.6	6.6	8.62	
								REJECTED	8	3	9	39	
DATA TREE SSS							TREE SSS	/ EKROR	8.00%	8.00%	6.60x	2911.0	
DATA							DATA	ERROR	9	3	0	89	
80 80	*	9	9	3	20		888	OKRECT	190.001	160.90%	100.001	100.001	/99.99 /99.99 /99.99
								0	=		-	3	
TREE	× :	3	2	9	78		TREE	1 / 0	180	181	100	160	FOR 12
LOGIC TREE	¥: ⊌.	3	3	45 0	82 3		LUGIC TREE	CORRECT / COMRECT	51 18	52 161	45 100	78 100	226 FUR 190.887 8 FOR 9.887 9 FOR 9.887
LOGIC TREE							LOGIC TREE	TOTAL CORRECT / C					VECTORS 226 CORRECT 226 FOR 12 ERROR 0 FOR REJECTED 0 FOR

TEST CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 2
FIGURE 12

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		31			REJECTED / REJECTE	8.06%	220.0	0 0.8KX	***************************************	
			1000年2月	DATA TREE FFF	*OR	200.0	×00.0	N-002	0.00x	
			T. S. S. A. S.	DATA	ERROR	Ø	5	5	8	
9	9	3	78 50 00	L L	ပ	100.001	100.00%	166.66%	100,00%	18 100.60/ 18 0.00/ 18 6.00/
. 0	S 03	45	0	LUGIC TREE	CORRECT	51	53	45	18	227 FOR 8 FOR 8 FOR
S1 U	.a 53	8	9		TOTAL	51	53	45	78	VECTORS CORRECT ERROR RÉJECTED
					CLASS	-	ے	w w	×	TOTAL OVERALL OVERALL OVERALL

DESIGN CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 3
FIGURE 13

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		7001	LOGIC TREE SSS	883	DATA	DATA TREE SSS	<i>></i>	
	00	E	×:	* ·		*		9
כ	51 6	9 .	7.9	9				
0	9 52	្ន	Э	9				S S IN S IN S
ш	5	. 45		3				
×	5	3	78	S				
04483							ALL DE CLEED	A RESERVE
		10010	LOGIC TREE	S S S	DATA	TREE SSS		
CLASS	TOTAL	CORRE	/ 13	CORRECT / COMRECT	ERROR	/ ERROR	REJECTED	/ REJEC
ח	215	51	1	180.06%	59	230.0	3	6.86%
o o	55	52		160,002	S	6.09X	3	W. 09%
Li p	21 45	45		100.00%	59	zen•a	9	820.0
×	87	78		100,022	ల	3.00%	8	W. 00x
TOTAL OVERALL OVERALL OVERALL	VECTORS CURRECT CRROR REJECTED		FOR	180.88/ 6.05/ 8.08/		even 1997		

TEST CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 3

		LUGIC TREE	REE WWW	DATA	DATA TREE WWW		
	0 0	ü	*				
5	51 6	20					* 4 0 0 * 2
. @ Q	6 53	3	3				
W	9	45	3				\$ 4 6 F E
× × × ×	9	9	0 87			WF WESTED	V MENETS
		Tunit 1					
		LOGIC TREE	EE WWW	DATA	TREE WWW		
CLASS	TOTAL	CORRECT	/ CORRECT	ERROR	/ ERROR	REJECTED	/ REJECT
>	15	51	100.001	6	0.00X	9	6.662
٥	53	53	100.001	5	0.00X	83	0. UEZ
E	45	45	100.00x	8	0.00x	3	E. 662
×	. 82	78	100.001	9	0.00x	5	279.0
TOTAL OVERALL OVERALL SVERALL	VECTORS COKRECT ERROR REJECTED	227 227 FG 60 FG	FOR 190.00/ FOR 0.00/ FOR 0.00/				

DESIGN CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 4

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CTED

DAK MAL	TANKE A	W1 0	LOGIC TREE	TRE		***	DATA	TREE	**		
		a	M	•	×	*					
_ 	51	9	•	tes.		5					25,8
٥	2 2 3	٨	5	ew.	3	2			X 00 . 0		30 * 60
12 W		, 5	45	ru	5						
36 X	0.	5	•	78	60	* S			25 CO 25 CO 25		0.04
684.33	10.00		£704			1318443				RESPECTED	
			1302	בערבי ומבי				THE			
¢			LOGIC TREE VVV	TREE			DATA TREE VVV	TREE	>		
CLASS	TOTAL		CORREC	13	5	CORRECT / CORRECT	ERROR	/ ERRUR	ROR	REJECTED	/ REJEC
.	51		51		160	100.001	9	0.06%	X 90	9	9.00x
٥	52		52		991	166,66%	5	0.00%	200	3	8.06%
w	45		45		991	100.001	9	N. 80%	× 90	9	6.66%
×	78		78		100	100.00%	8	9.	0.00x	0	8.00%
FOTAL SVERALL SVERALL SVERALL	VECTORS CORRECT ERROR REJECTED	0	226	FOR	2	100.001 6.00/ 6.00/					

TEST CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 4

FIGURE 16

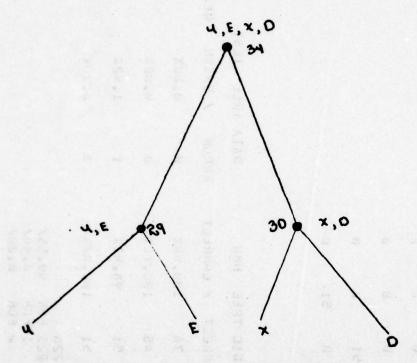
THE STATE OF THE STATE OF

		ί	219	TREE	LOGIC TREE HAH	DATA	DATA TREE DESIGN	IGN	
SAZ.	x :	ш	a	3	(A) (A) (A)		0.862	*	
×	78	0	3	3	1	•	71 8 814.8		\$ * c.m.)
W	4 150	45	3	3	National P				\$10 50 50 50 90
0	- A 7 8 7	O COM	53	2	CONTROL				A RESERVED
>	9	5	3	51	L AAA 0				
		10	213	LOUIC TREE	H	DATA	DATA TREE DESIGN	IGN	
CLASS	TOTAL	00	CORRECT		/ COKRECT	T ERROR	/ ERRUR	REJECTED	/ REJECTED
×	78		.78	20 1	100.001	5	N. 66%	5	xan.a
w	45		45		100.001	S	200.0	3	0.66%
<u>a</u>	53		53		160.001	6	0.00x	5	X 99 . 9
•	51		51		160.00%	5	200.0	0	0.00x
TOTAL OVERALL OVERALL OVERALL	VECTORS CORRECT ERROR REJECTED	1.06	227	FOR	186.88/	ATAQ	WE'F BAA		

DESIGN CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 5 FIGURE 17

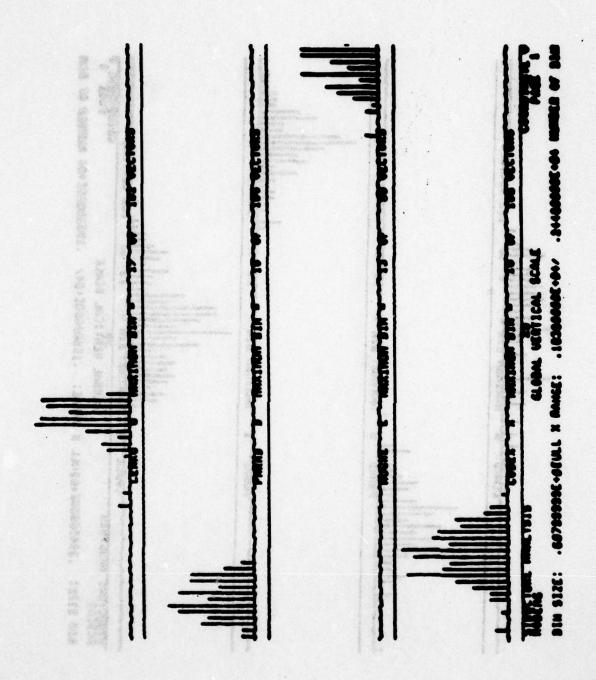
								/ REJECTED	*	×	7.	14.	
								/ RE.	8.662	W. 06%	8.0UX	290.5	
								REJECTED	3	9	3	0	
IREE TEST							DATA TREE TEST	/ ERRUR	3.60%	N. COX	1.92%	N. 662	
DATA TREE		. 76					DATA 1	ERROR	5	3	•	59	
HH	*	9	3	S	S		H	CORRECT / CORRECT	189.082	190.061	98.07%	100.002	99.55/ 6.44/ 6.60/
TREE	5	3	3	S	51.		TREE	1	16	1.6	5	16	\$5.5 \$ 3.5 \$
LOGIC TREE	3	9	3	51	e.		LOGIC TREE HAN	CORREC	78	45	51	51	225 225 1
	x :	78 W	9 45	1 6	9			TOTAL	78	45	25	51	VECTORS CORRECT ERROR REJECTED
		*	ш	0	5			CLASS	×	ш	a	2	OVERALL COVERALL COVERALL COVERALL COVERALL COVERALL FOR

TEST CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 5

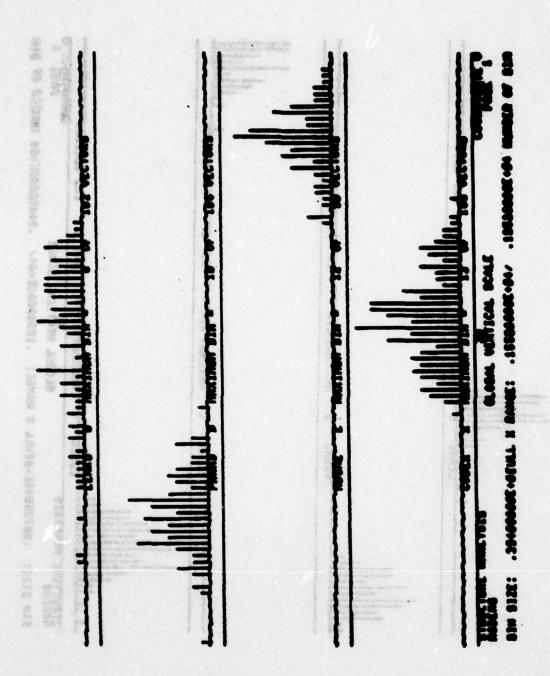


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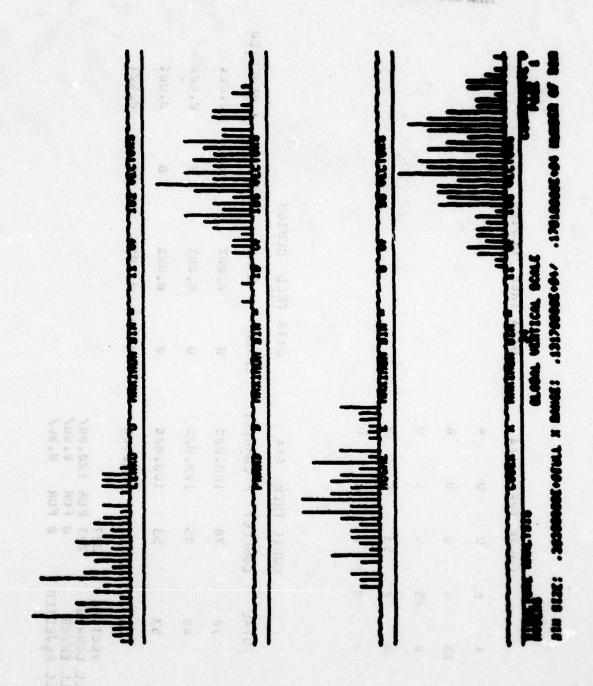
LOGIC TREE STRUCTURE FOR EXPERIMENT 5



PROJECTION ON 29th FEATURE DIRECTION FIGURE 20



PROJECTION ON 30th FEATURE DIRECTION FIGURE 21



PROJECTION ON 34th FEATURE DIRECTION
FIGURE 22

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	and the second	LOGIC	TREE	LOGIC TREE AAA	DATA	DATA TREE DESIGN	SIGN	
	ж:	۵		*				
×	78 6	3		S				
u	6 45	Э	•	3				
٥	2	53		5 9				
,	5	3	21	3			X	
		LOGIC TREE	TREE	AAA	DATA	DATA ŢRĒE DESIGN	IGN	
CLASS	TOTAL	CORREC	1:	CORRECT / CORRECT	ERROR	/ ERRUR	REJECTED	/ REJECTED
×	78	7.8	-	169.691	9	299.9	9	6.86%
w	45	45	-	169.60%	8	N. 662	20	8.65×
۵	53	53	-	104.46%	5	6.00%	3	0.00%
5	15	51		190.001	9	N.00%	9	8.66%
TOTAL OVERALL OVERALL OVERALL	VECTORS CORRECT ERROR REJECTED	227	T T C S	166.66/				

DESIGN CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 6

FIGURE 23

10.49.80.C

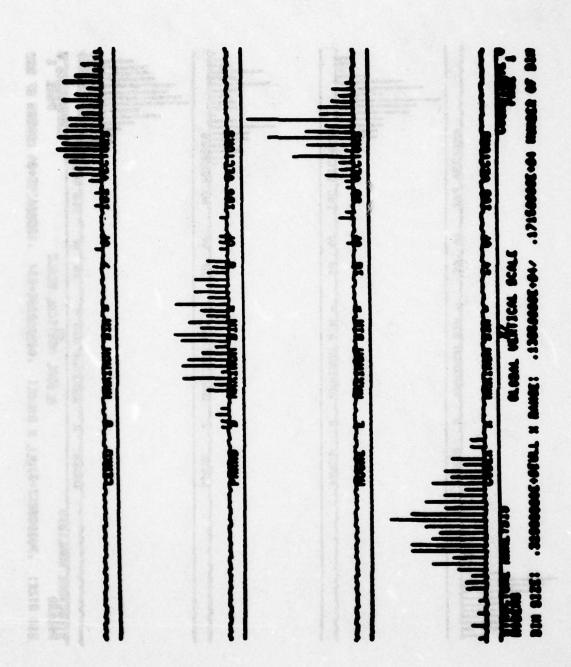
							DE TECTED / DE TECTED	×96.8	290.0	290°9	299.0	
DATA TREE TEST						0 v. 2	DAIA TREE TEST		N. 66%	N.06%	N. 66%	
DATA							FRROK	9	3	23	9	
EE AAA	*.	9	9	9	51 6		CORRECT / CORRECT	160.96%	100.001	100.001	100.00%	160.88/
LOGIC TREE	a.	.a	3	52	83		CORRECT / CORRE	78	45	52	51	226 226 FOR 8 FOR
	ж: ж	n 81	W 45	9			TOTAL	78	45	52	51	VECTORS CORRECT ERROR
		×	B	٥	-		CLASS	×	w	a	n	OVERALL OVERALL OVERALL OVERALL

TEST CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 6

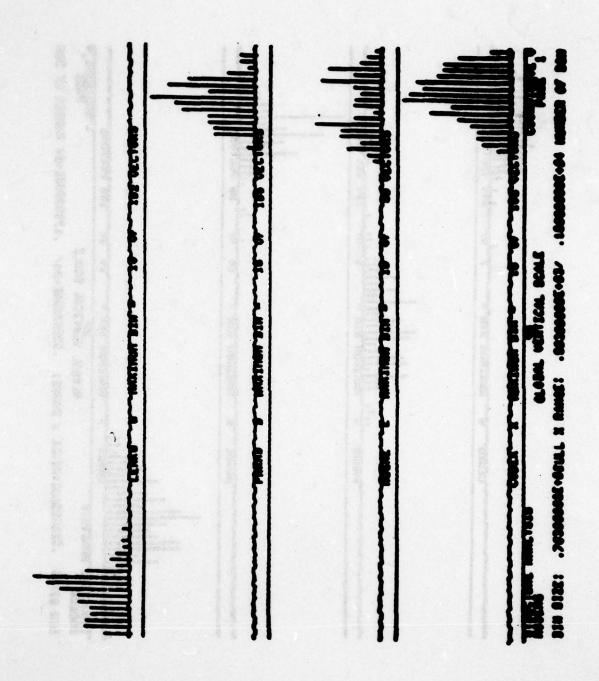
W,E, X,O > 27

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LOGIC TRFE STRUCTURE FOR EXPERIMENT 6
FIGURE 25



PROJECTION ON 27th FEATURE DIRECTION FIGURE 26



PROJECTION ON 46th FEATURE DIRECTION
FIGURE 27

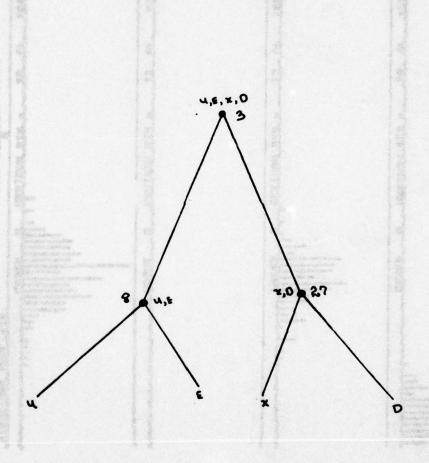
/ REJECTED 80000 9.004 0.062 8.062 REJECTED 2 DATA TREE DESIGN DATA TREE DESIGN / ERRUR 200.0 8.80x N.00x N. 00% ERROR 3 0 / COMRECT 100.00/ 0.00/ 0.00/ LUGIC TREE YYY 100.00% 0 100.001 100.001 100.00% YYY LOGIC TREE 2 FOR CORRECT 78 227 45 53 21 53 2 3 45 REJECTED VECTORS CORRECT ERROR TOTAL 78 45 53 51 2 (3) 5 OVERALL OVERALL OVERALL CLASS TOTAL

DESIGN CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 7

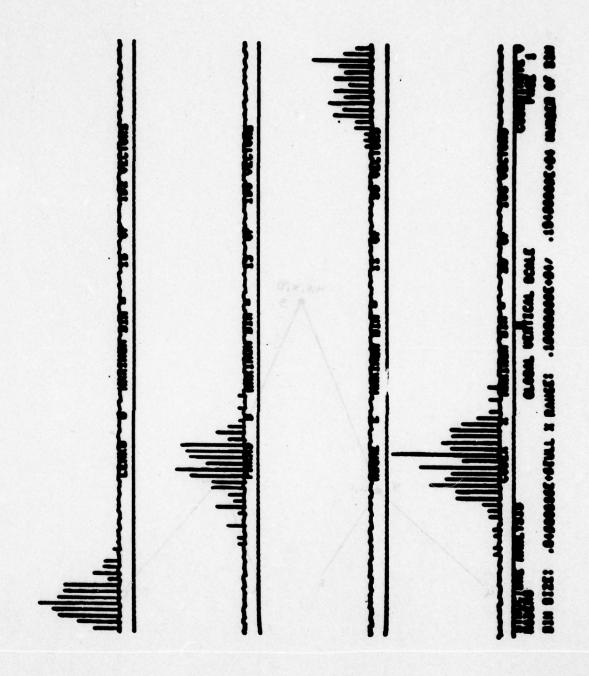
		1.0610	LOGIC TREE YYY	DATA	DATA TREE TEST		
	×.	E D	*.				
×	78	9 9	5				
E	6 45	3	3				
0	9	0 52	3				
28 7 75	5	9 6	51 0			H 8 2 7 7 10 10	
						NO.	
		LUGIC TREE	TREE YYY	DATA	DATA TREE TEST		
CLASS	TOTAL	CORRECT	T / COKRECT	ERROR	/ ERROR	REJECTED	/ REJECTEU
×	78	78	100.001	8	200.0	8	8.88x
Э	45	45	100.00%	39	8.00x	0	¥99.0
٥	52	55	100.00%	53	N. 00x	9	8.86x
>	51	51	100.002	5	N. 80%	9	# 90° B
TOTAL OVERALL OVERALL OVERALL	VECTORS CORRECT ERROR REJECTED	22.6	FOR 188.80/ FOR 8.88/ FOR 8.88/	ATAG			

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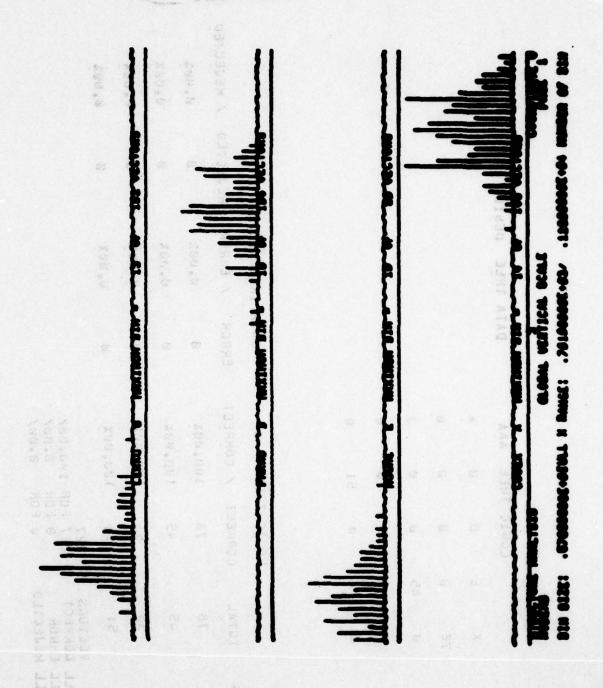
TEST CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 7



LOGIC TREE STRUCTURE FOR EXPERIMENT 7
FIGURE 30



PROJECTION ON 8th FEATURE DIRECTION
FIGURE 31



PROJECTION ON 3rd FEATURE DIRECTION
FIGURE 32

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		LOGIC TREE	TRE	E AAA	DATA	DATA TREE DESIGN	IGN	
	×:	a		*.				ton Life party Party Color Party Color Party Color
×	78 6	9		9				District est
E NO	ы 45	3		9			eth i	Section and the second
	3	53		3				
o na n	9	\$	51	0				
FRATUR	CONTRACTOR (SEE SECTION)							
Dyf N		LOGIC TREE	TREE	××	DATA	DATA TREE DESIGN	N91	
CLASS	TOTAL .	CORRECT		/ COMRECT	ERROR	/ ERROR	REJECTED	/ REJECTED
×	78	78		100.00%	9	8.00x		×99.9
E CORP	45	45		100.001	9	0.00x	50	×90.8
٥	53	53		100.001	9	W. 66X	0	0.00x
2	215	51		196.60x	•	6.66%	0	200.0
TOTAL OVERALL OVERALL OVERALL	VECTORS CORRECT ERROR REJECTED	227	FOR	186.08/				

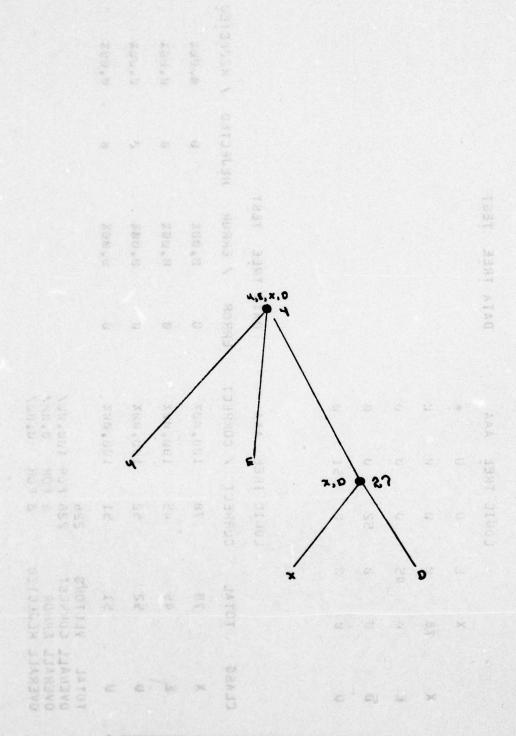
DESIGN CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 8

THE STANK ALL OF

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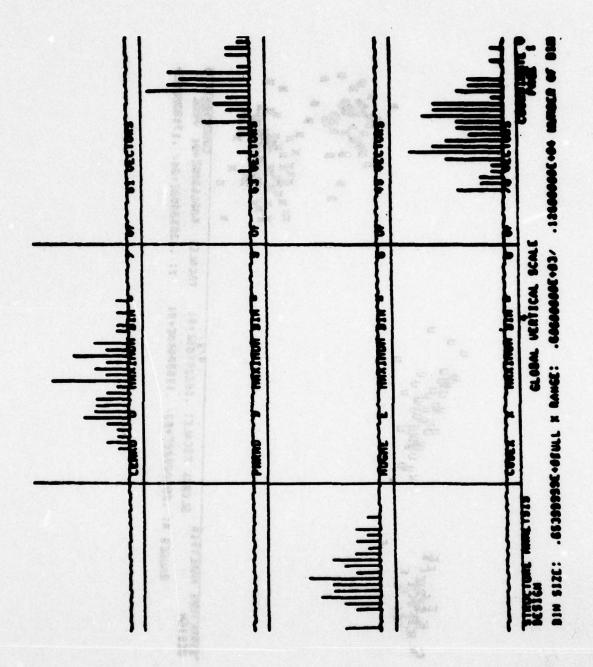
								/ REJECTED	8.06%	X99.8	23P.9	6.00%	
								REJECTED	\$	2	9	29	
DATA TREE TEST							DATA TREE TEST	/ ERRUR	N. 86x	8.00%	N.00%	200.0	
DATA						100	DATA	ERROR	9	5	29	9	
AAA	« ·	S	8	Ø	3		AAA	/ COKRECT	160,66%	100.002	100.001	168,68%	226 FUR 188.88/ 8 FOR 8.88/ 8 FOR 8.88/
TREE	>	2	2	3	51		TREE		-	-	7	=	FOR
LUGIC TREE AAA	3	3	3	52	20		LOGIC TREE AAA	CORRECT	78	45	52	51	226
	×	78 6	6 45	5	2			TOTAL	7.8	45	25	51	VECTORS CORRECT ERROR HÉJECTED
		*	E	0	5			CLASS	×	w	a	5	TOTAL VOVERALL COVERALL E

TEST CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 8



LOGIC TREE STRUCTURE FOR EXPERIMENT 8

100 M



PROJECTION ON 4th FEATURE DIRECTION
FIGURE 36

1,8 The 20 303

TWO-SPACE SCATTER PLOT (MEASUREMENTS 4 AND 27)
FIGURE 37

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			LOGIC TREE	TREE	design	DATA	DATA TREE O	oesign	
	x :	Ä	0	3	* 1500				2007
×	78	2	2	3	5				
æ	9	45	3	3	9				
٥	5	2	53	3	9				
ח	9	59	3	51	2				
			LOGIC TREE	TREE	Ge si co	DATA	DATA TREE geston	es co	
CLASS	TOTAL		CORREC	-		ERRUR	/ ERRUR	R REJECTED	TED / REJEC
×	. 78		/8		160.66%	3	W. 66%	20	, 1942, 8
u U	45		45	-	150.00X	Э	N. 00%	3	799.6
0	53		53	-	169.66%	29	×99.5	53	*49.6
ם	5.1		51	-	164.602	3	0.66%	3	299.9
TOTAL OVERALL OVERALL OVERALL	VECTORS CORRECT ERRUR RÉJECTED		227	FOR	227 FUR 100.007 6 FOR 6.007 6 FOR 0.007				

DESIGN CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 9

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				100.00/ 0.00/ 0.00/	FOR 1	226 226 FUR 6 FUR 0 FOR	VECTORS CCRRECT ERROR REJECTED	TOTAL OVERALL OVERALL OVERALL
200.0	9	N . 88%	0	160.002	16	51	51	-
6.06%	5	8.00x	9	100.001	16	52	52	a .
200°9	9	×00.0	3	100.001	31	45	45	a.
200.2	8	8.00%	3	160,662	31	78	78	×
/ REJECIE	REJECTED	/ EKROR	ERROR	/ CONRECT		CORRECT	TOTAL	CLASS
		DATA TREE TEST	DATA	LOGIC TREE design	TREE	7007		
				9	51	9	6) D
				. 6	3	55	9	0
				¥	3	3	E 45	Z Z
				9	.20	5	78 0	×
					7	3	×	
		DATA TREE TEST	DATA	design	TREE	LUGIC TREE		

TEST CONFUSION MATRIX WITH STATISTICS FOR EXPERIMENT 9

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LOGIC TREE STRUCTURE FOR EXPERIMENT 9
FIGURE 40

VIII. DISCUSSION AND RECOMMENDATIONS

The success the classifiers had in the problem of modem identification is proportional to the quality of the features provided by the FOBW method. The question remains as to what aspect of the modem's functioning these features were reflecting which provided such excellent discriminatory quality. One way to approach this question is by obtaining the auto-correlation of a number of sample waveforms from each modem. This approach is suggested by the fact that the FOBW method operates in a manner similar to that of obtaining an auto-correlation. Cross-correlation between the different modem waveforms might also provide information.

Another important issue is that the data was, after all, collected in a laboratory, not in the real world. To fully test the performance of the classifiers designed using the data provided, it would certainly be necessary to obtain data from the more realistic environment. Should the classifiers' performance drop after being exposed in the field, information provided by the auto-correlations and cross-correlations obtained previously might suggest other, better features by way of the same FOBW method.

APPENDIX A

PARLAN PROGRAM LISTINGS

LISTING OF PROGRAM BINSED

COMMENT COMMENT COMMENT COMMENT IF A POINT ON WI IS >0 A (1) RESULTS COMMENT IF A POINT ON WI IS <=0 A (0) RESULTS COMMENT IF A POINT ON WI IS <=0 A (0) RESULTS COMMENT IF IZ0=0 IF HE RANGE TO BE BINARY SEQUENCED COMMENT COMMENT IF (120=0) GOTO 200 LET I1=NPT(WI) IF (120=0) GOTO 200 LET I1=NPT(WI) IF (120=1) GOTO 400 LET I1=NPT(WI) IF (190=0) LET 19=0 IF (190=0) LET 19=0 IF (190=0) LET 19=0 IF (190=0) LET 19=0 IF (190=0) LET 19=1 IF (190=0) LET 19=1 IF (190=0) LET 19=1 IF (190=0) LET 19=1 IF (190=0) LET 19=0 IF (190=0) LET 19=1

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LISTING OF PROGRAM FORM80

SUBROUTINE FOBM80(M1) V1)

COMMENT PURPOSEITU COMPUTE THE FREQUENCY OF OCURRENCE OF COMMENT THE BINARY WOKDS "11", "10", "01", AND "00" WITH DELAYS COMMENT INPUT---WIBINARY SEQUENCED WAVEFORM COMMENT OUTPUT---V1180 DIMENSIONAL VECTOR (80 FEATURES) COMMENT 2LT FERNANDEZ 11 MAY 78 IF (117=1 & 118=0) GOTO 75 LET 16=W1(14+11) IF (15=1 & 16=1) GOTO 25 DU 100 11=1,200,10 LET 13=12-11 LET 110=0 LET 160=160+1 DO 50 14=1,13 LET IS=W1(14) DO 206 114=1,200,10 118=W1(116+114) DO 150 116=1,115 LET 117=M1(116) LET VI(160)=110 CONTINUE LET 115=12-114 LET IZ=NPT(MI) LET 160=160+1 LET 110=110+1 LET 128=120+1 120=0 LET 160=0 CONTINUE G0T0 150 CONTINUE 6010 58 300 100

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LET V1(160) #120

200 CONTINUE

DO 300 124#1, 200, 10

LET 125#12-124

LET 130#0

LET 150#0

LET 150#0

LET 160#160+1

DO 250 126#1, 125

LET 160#160+1

255 LET 130#130+1

256 CONTINUE

LET 130#130#1

257 CONTINUE

LET 130#134

LET 130#0

LET 135#160 #1

LET 130#160) #134

LET 130#160) #140

A00 CONTINUE

LET 130#140 #1

SEG CONTINUE

PRINT VI

VEND VI

RETURN

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LISTING OF PROGRAM AVERGE

PURPOSE : TO CUMPUTE THE AVERAGE OF A MAVEFORM AND THEN SUBTRACT THIS AVERAGE FROM EVERY POINT OF THE WAVEFORM (REMOVE BIAS). OUTPUT WAVEFORM IS SET TO BE ISO POINTS LONG. NPT OF INPUT WAVEFORM MUST BE >8130. 2LT FERNANDEZ 1 JUNE 78 SUBROUTINE AVERGE (M1, 1301M2) LET 11=NPT(M1)

IF (11<130) GOTU 500

IF (11>130) LET 11=130 LET 110m0 DO 100 12m1(12) LET 13=W1(12) 110=110+13 DO 200 14=1,11 CONTINUE LET 128=110/11 16215-120 15=W1(14) W2(14)=16 PRINT 120 MAVEND M2 CONTINUE RETURN LET COMMENT COMMENT COMMENT COMMENT COMMENT COMMENT COMMENT COMMENT LET 500 200 100 991 202222222 202222222

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LISTING OF PROGRAM ANYSEC

10 20 01	SUBROUTINE ANYSEC(M1, 110, 120, 130, 140;W2)
20	
30	COMMENT IF IIO AND IZU ARE BOTH NOT EQUAL TO ZERO THEN THE
40	
50 388	
835 09	IF BOTH 116 AND 128 ARE EQUAL
70 50%	DENOTE THE RANGE OF THE INPUT MAVEFORM TO
80 50	
90 300	COMMENT 2LT FERNANDEZ 14 JULY 78
100	D. S. S. C. Constant of Constant
11658	IF (11826 & 12828) GOTO 108
120	IF (120=0) GOTO 500
130	LET 11shPT(M1)
140	LET 12=110/120
150	LET 13=11#12
160	DO 16 14=1, 13 perty party and the perty p
170	LET 15=11(14)
180	10 CONTINUE
190	6010 400
288	160 LET 11sNPT(M1)
210	IF (140>11) GOTO 500
220	LET 18s0
230	DO 300 14=130,140
240	LET 18s18+1
250	LET 15sH1(14)
260	LET W2(18)=15
270	CONTINUE
288	480 MAYEND WALLEDISTERNISTED DINCHAIGNET SECTOR OF SEVENSES
670	ANGELEKE TABBLANNATERISPEA PERINEMENT MYSELSMA
Or a	的人名的名称 好以所以 与持者行为 中一日
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	作品の (1) 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

A-40 E. E. C.

THE PROPERTY OF

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COMMENT PURPOSEITU COMPUTE THE FREQUENCY OF OCURRENCE OF COMMENT THE BINARY WOKDS "1,1", "1,0" WITH DELAYS COMMENT INPUT---WISB DIMENSIONAL VECTOR (50 FEATURES) COMMENT OUTPUT---VIISB DIMENSIONAL VECTOR (50 FEATURES) LET 12=NPT(W1) LET 12=NPT(W1) LET 160=0 DO 100 11=1,25,1 LET 110=0 LET 10=0 LET 10=
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              IF (117=1 & 118=0) GOTO 75
GOTO 150
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         IF (15=1 & 16=1) GOIO 25
SUBROUTINE FOBMSB(M11V1)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             LET 118=W1([16+114)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    LET 160=160+1
DO 150 116=1,115
                                                                                                                                                                                                                                                                                                                                                                                                                                                                DO 50 14=1,13
LET 15=W1(14)
LET 16=W1(14+11)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             DO 260 114=1,25,1
LET 115=12-114
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       LET V1(160)=110
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          LET 117=W1(116)
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            LET V1(160)=120
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 LET IIBEIIB+1
CONTINUE
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  LET 120=120+1
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APPENDIX B

SAMPLE 50 DIMENSIONAL VECTOR
FROM EACH MODEM (CODEX, HUGHES,
PARADYNE, LENKURT, RESPECTIVELY)

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